Created wetland soil development after four years of flooding (October 2000)

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Introduction

The "no net loss" policy from the National Wetlands Policy Forum of 1987 was developed "to achieve no overall net loss of the nation's remaining wetlands base and to create and restore wetlands, where feasible, to increase the quantity and quality of the nation's wetland resource base" (National Wetlands Policy Forum, 1988; Mitsch and Gosselink, 2000). Consequently, wetlands can continually be destroyed as long as new mitigation wetlands of the same size or larger are created. Failure of function is a known destiny for created and restored wetlands.

Success in creating a wetland is greatly dependent on understanding the processes which occur, particularly with regard to the interactions and dynamics between the hydrological components and the biotic and abiotic components (Gilbert et al., 1999). In the determination of succession of created and constructed wetlands, soil characteristics are a very important factor. Hydric soils are an indicator of wetland succession.

Color, bulk density and organic matter are all indicators of hydric soils (Mitsch and Gosselink, 2000). Saturation acting in conjunction with decomposition of organic matter leads to anaerobic conditions and reduction of the soil (Mitsch and Gosselink, 2000). Reduction of iron and manganese, called gleying, gives soil the darker color characteristic of wetland soils (Mitsch and Gosselink, 2000). The buildup of organic matter also contributes to the darkening of the soil (Bishel-Machung et al., 1996; Confer and Niering, 1996) and indicates reduced conditions as degradation slows down. Bishel-Machung et al. (1996) found lower bulk densities in reference wetlands compared to created wetlands, indicating that succession of wetland conservation was not achieved within the time period elapsed.

A wetland was created in 1996, called the billabong, as part of a mitigation project in the Olentangy River Wetland Research Park (ORWRP). The billabong is located next to the kidney shaped marshes that symbolize the ORWRP (Wetland 1 and 2). It has not been as intensively studied as Wetland 1 and 2 because of its young age.

The present study determines the physicochemical properties of soils in the billabong and surrounding uplands at the ORWRP in October 2000. The soils are classified according to color, bulk density and percent organic matter content. The results are compared to previous data from the billabong and the adjacent wetlands. Furthermore, they are compared to other mitigation wetlands across the country.

Methods

Site Description

The Olentangy River Wetland Research Park (ORWRP) is located on 10 hectares of previously farmed fields at the northern end of The Ohio State University campus. It is within the Olentangy River flood plain and is underlain with 33 to 83 m of glacial out-wash deposit (Gilbert et al., 1999). The soils are of the Ross and Eldean series and consist of silt loam, silt clay, and clay loams (Mcloda, 1980; Mitsch, 1993).

The research park consists of two 1-ha experimental marshes and a groundwater fed marsh called the billabong (Figure 1). The billabong was developed as a mitigation project in the autumn of 1996 and designed to function as a riparian system. It is fed by river water during periods of high water levels and is also influenced by groundwater. It is mainly wet in the winter and spring and experiences dry periods during summer months, which is a typical hydroperiod pattern for riparian wetland systems throughout Ohio.

Field Work

Soil samples were collected from the billabong along transects that represent different degrees of inundation, namely upland, transition and deep-water locations (Figure 1). All cores were obtained using a 2 cm diameter stainless steel handheld soil probe and performed in triplicates. The hues, values and chromas of the top 0-8 cm and the bottom 8-16 cm soil were determined in the field using a Munsell, Color Chart. The top 0-8 cm and bottom 8-16 cm of the samples were placed separate in glass jars, sealed with a lid, and then frozen until analysis.

Laboratory Analysis

All of the samples were air dried, sieved in a 2 mm sieve, weighed and dried in the drying oven at 110°C for 12 hours. Samples were then re-weighed to determine bulk density as the dry weight to sample volume ratio. After burning in a muffle furnace at 550°C for two hours, samples were weighed to determine percent organic matter (Dean,

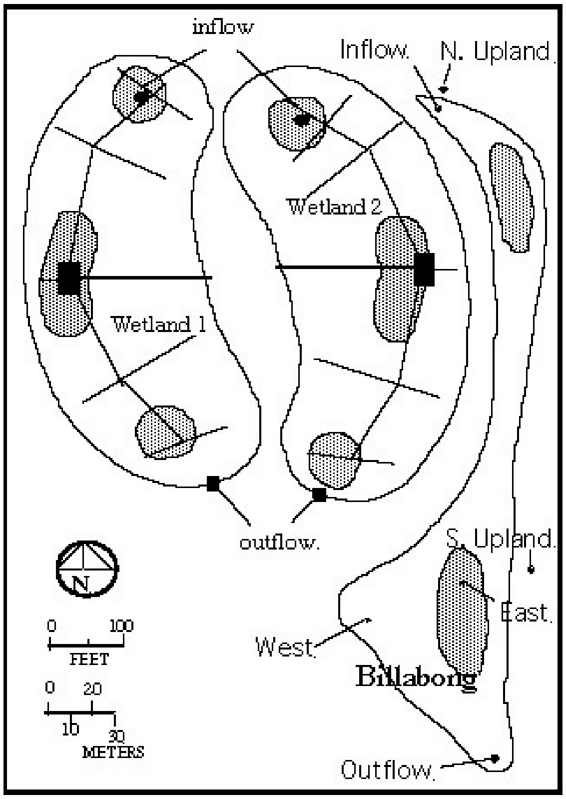

Figure 1. Billabong soil sampling sites at the Olentangy River Wetland Research Park in 2000.0

1974). This was done by subtracting post-burn weight from the pre-burn weight and dividing by the pre-burn weight (Boyd, 1995).

Data Analysis

Soil samples for each depth were averaged and standard errors calculated. The data frequency distribution and mean versus variance were graphed to determine if ANOVA assumptions were met. ANOVAs were performed for bulk density and percent organic matter to the .05 percent levels. Student Newman-Keuls (SNK) tests were then used to compare the relationships between sites. Once depth was determined not significant the SNK test was ran combing depths for site differences. Data from 1998 was compared to present data for an overall outlook in soil development. Due to differences in site locations data were not statistically compared.

Results

Munsell Color Chart

Hue, value and chroma were assigned to each core and averages were reported for each depth and site (Figure 2). All sites had values of three and all sites within the Billabong, except for the eastern site, displayed hues of 2.5Y in the upper 8 cm. Inflow and outflow sites showed chromas of 2 indicating hydric soils. The north and south upland sites had ratings of 10YR 3/2-3/3 indicating that billabong soils are very similar to areas immediately outside of the wetland. The east site had a rating of 10YR 3/6 which was least similar to all sites at that depth. In soils from 8-16 cm, there were no values that indicated hydric soils (chroma of 2 or less). The inflow and the eastern site seemed to be the least indicative of hydric soils (10YR 4/4). Ratings from the Munsell chart indicate that soils of this depth are still very similar to samples found outside of the immediate billabong wetland.

Table 1. Pattern key for this study.

Color	Value	Chroma
2.5Y	3	2
2.5Y	3	3
10YR	3	2
10YR	3	3
10YR	3	4
10YR	3	6
10YR	4	4

Bulk Density

Bulk density (0 - 8 cm) ranged from 0.72 ± 0.11 g cm^{-3} at the inflow to 1.32 ± 0.10 g cm^{-3} at the eastern site (Figure 3). Values for core sections representing 8-16 cm showed the eastern site having the second highest value (1.46 ± 0.13 g cm^{-3}) and that the inflow was the lowest again (1.15±0.15). ANOVA results showed interactions ($P<0.005$) between depths and sites (Table 2). This can be seen in the data table displaying mean values for bulk density (Table 1). ANOVA analysis also displayed bulk density varying significantly between sites ($P<0.02$). Student Neuman-Keuls tests revealed eastern site values were significantly different than all other sites. All other sites were similar statistically. Depth analysis was also significant ($P<0.0001$). Bulk density 0-8 cm was significantly less than 8-16 cm depths.

Percent Organic Matter

At depths of 0 - 8 cm the percent organic matter is higher at the inflow, western and outflow sites (3.97 ± 0.60 - 4.87 ± 0.51%) than the upland sites (Figure 4). This indicates soils are starting to change after four years of wetland conditions. However, the east site continues to show dissimilar results. Its percent organic matter value (3.97 ± 0.81%) is equivalent to the lower values seen at the upland sites (Table 1). The northern upland site displays a low percentage due to one unusual sample that could not be discredited. Percent organic matter at lower depths in the wetland and upland are similar indicating that there is little change toward hydric soils at this soil depth. ANOVA results showed that there were no significant interactions between site and depth ($P>0.05$), depths ($P>0.05$), or sites ($P>.05$) (Table 3).

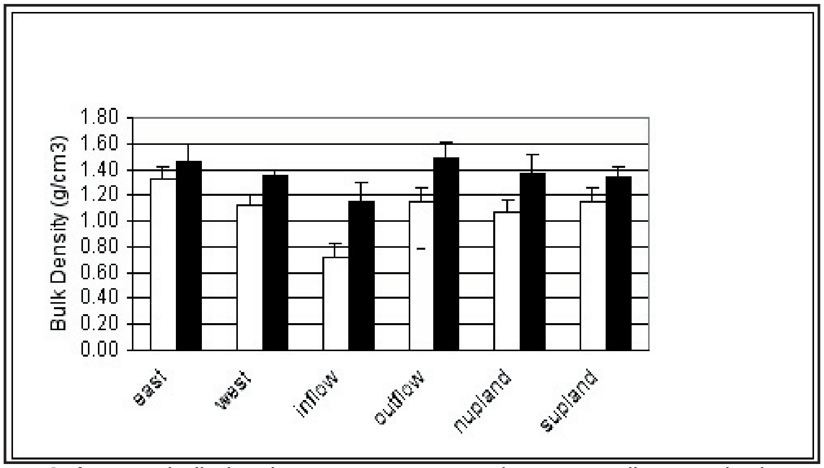

Figure 2. Average bulk density measurements and corresponding standard error at sampled sites.

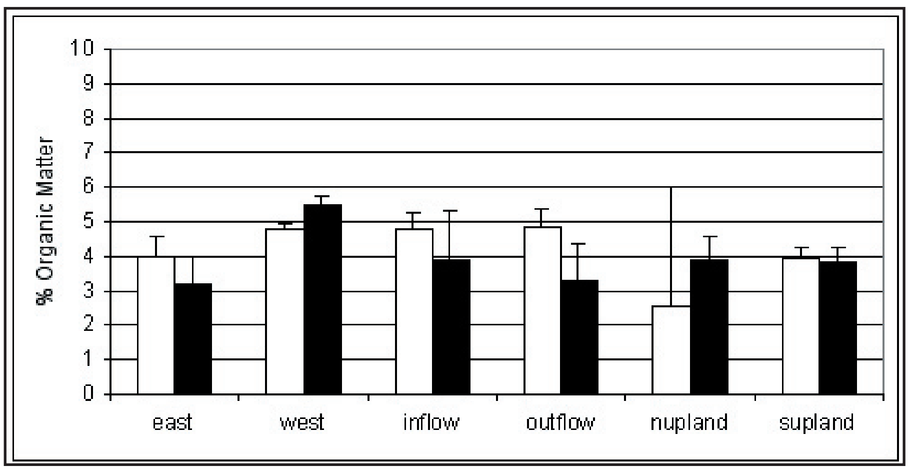

Figure 3. Average percent organic matter measurements and corresponding standard error at sampled sites.

Table 2. ANOVA analysis for bulk density at depths 0-8 cm and 8-16 cm (alpha=0.05).

Source of Variation	DF	SS	F	P
Total	35	2.345		
Treatment	11	1.480		
Depth	1	0.653	0.653	<0.001
Site	5	0.746	0.764	<0.02
Depth vs Site	5	0.827	0.826	<0.005
Error	24	24	0.036	

Comparison with 1998 data

Data at one sampling site in the 1998 soil analysis was a similar area and similar depth. A 95% confidence level revealed that bulk density in 1998 (1.46 g cm^{-3}) was statistically different from the western site (1.24 ± 1.96 g cm^{-3}). A similar analysis of percent organic matter for 1998 data (3.40g cm^{-3}) was also statistically lower than 2000 data (5.12 ± 1.96 g cm^{-3} (0.214)). There has been change in the soil towards greater organic soil accumulation and lower bulk density at this location but this may not reflect the entire wetland area.

Discussion

Munsell Chart

Results from the 1998 Munsell chart readings portrayed soils with a small muck layer, values of 4-3 and chromas ranging from 4-2. Only one soil core showed a chroma of 2 in the 0-10 cm portions. Data from 2000 shows a darkening of soil color with all values for 0-8 cm equaling 3 and a tendency toward hydric soils represented by chromas of 2-3. It should be noted that readings in the wetland were similar to readings at the upland sites that were used as comparisons to previous soil conditions. According to Mitsch and Gosselink (2000) tendencies towards darker soils and lower chroma values signify a shift toward hydric soils. The 8-1 6 cm soil portion does not display change from 1998 readings or 2000 upland sites. Accumulation of organic matter takes several years and will take longer to affect these depths. Gilbert et al. (1999) suggest that soils are less hydric due to the youth of the billabong and less frequent flooding time representative of this wetland type. One interesting result of different site locations within the billabong is the difference displayed by the eastern site. The readings at this site were 10YR 3/6 and 10YR 4/4. Both results had chromas equivalent or greater than upland sites suggesting this portion of the wetland is not progressing as other portions. One possible reason for this anomaly could be the eastern sites location away from the main water flow pathway.

Bulk Density

Bulk density measurements for mineral soils usually range from 1-2 g cm^{-3} but may be higher for tightly compacted soil (Boyd, 1995). Organic soils only reach levels of 0.2-0.4 g cm^{-3} and often contain peat. The bulk density values at the wetland indicate mineral soils. Mitsch and Gosselink (2000) suggest that freshwater marshes often contain mineral soils overlain by a layer of organic matter from vegetation productivity. Greater bulk density at greater depths may result in greater soil compaction or symbolize greater time needed for organic accumulation to reach this soil layer. Upland sites outside the billabong were similar to all sites in the wetland except the eastern site. Either these two sites are experiencing similar flooding/vegetation changes as the sites within the billabong or little change has occurred.

Comparisons with 1998 data reveal bulk density decreasing at the western site. Uncertainty in 1998 value location, depth, and lack of replication throughout the wetland give this number little credibility. Other 1998 bulk density values are lower but locations are not comparable to other sites in this study. These data points would fit into 2000 confidence limits showing little change in soil bulk density. Looking at map locations, the eastern site seems protected from the direct flow path of water in and out of the Billabong. This may be effecting the formation and density of soils at this location. A study of the Shark River Estuary showed greater bulk density in riparian wetlands with increasing proximity to the estuary (Chen and Twilley, 1999). Though riparian processes are not the same as estuary processes, this area could be experiencing similar influences from slower flow and greater sedimentation rates.

Compared to other wetlands, the bulk density at the billabong is normal for a created wetland. Bulk density measurements averaged 1.4 g cm^{-3} at two experimental wetlands at the Olentangy River Wetland Research Park in 1994, 1996, 1997, and 1998 (Gilbert et al., 1999). Studies of 95 wetlands in Portland, Oregon showed bulk density ranges from 1.1-1.6 g cm^{-3} in natural and created wetlands (Chen and Twilley, 1999). From data, the authors concluded that bulk density is comparable in all wetlands soils including mitigated sites where soils were excavated. Studies on the Susquehannah River used 20 reference palustrine wetlands compared to 44 wetland creation projects (Bishel-Machung, 1996). The average bulk density was significantly higher for created wetlands (1.15 g cm^{-3}) than reference wetlands (0.60 g cm^{-3}). This study further supports that billabong bulk density measurements are similar to other created wetlands but disputes the previous study that bulk density is similar for all created and natural wetlands.

Organic Matter

The percent organic matter did not vary significantly with depth or site measurements. Lack of significant differences between the upland reference sites and sites within the billabong show either reference sites were not far enough from the Billabong or that little change has occurred from original soil matter content. According to Mitsch and Gosselink (2000), percent organic matter in riparian and freshwater wetlands is variable depending on hydrology and climate. Also, levels of 5% organic matter are suggested as good indicators of periodically flooded locations and arid western riparian systems are noted as having lower percentages due to younger soils. The billabong soils are only slightly lower than the 5% indicating near appropriate levels. The only way to determine that they are nearing appropriate levels is to compare these levels to other Ohio wetlands experiencing similar hydrology and geomorphology.

This data is compared to 1998 data to observe if a change in soil matter accumulation can be seen. Only one 1998 soil sample site was in a similar area, and this measurement fell below the 95% confidence limits of the 2000 sampling data (3.4%). This suggests increases in percent organic matter. It should be noted, that the western sampling site in our 2000 study had greater percent organic matter than other billabong sites. Most 1998 soil samples ranged around 3% organic matter while 2000 sites range around 4%. This indicates more credibility to change occurring and refutes this as a result of erroneous data. If the previously mentioned value of 5% is considered a goal then the billabong is already making significant movement towards it. This would suggest either that the time period required for proper organic soils to form is not long for riparian systems or design methods were more appropriate in this mitigated wetland. Determination of soil formation success for the billabong is difficult to determine without knowing if it should be compared to other wetlands with similar location and hydrology or if success depends on reaching levels of the wetland it replaced. Many studies have tried to determine which is more feasible but the larger debate is if failed wetlands need more time or if they will never achieve proper function due to poor design.

A study in Portland, Oregon compared natural and mitigated sites (Shaffer and Ernst, 1999). Constructed wetlands had lower soil organic matter at both measured soil levels than surrounding natural wetlands. Neither did they find a relation between time and accumulation of soil organic matter. This study suggests that amounts of organic matter in the soil depends more upon proper site development than time scale as suggested in other studies. Studies that show no relationship with age of constructed wetlands and percent soil organic matter may pinpoint cases of successful design if levels are found to be near or at natural wetland levels. Thompson et al. (1995) also showed that four year old mitigated wetlands had less organic carbon and nitrogen than adjacent natural marshes. Craft et al. (1988) suggests that salt marsh studies showed formation of ecological attribute as being so slow that more than 15 years are required and that constructed wetlands will remain inferior to natural wetlands. One must question present mitigation construction practices if time periods for development are long in some constructed wetlands while short in others. Should mitigation be allowed at its current pace if we are unsure if lack of time or design is the problem? Changes in the Billabong, which is not permanently flooded, are occurring slower than changes have been observed in the two permanently flooded wetlands adjacent to it at the Olentangy River Wetland Research Park. This may indicate system hydrology changes the amount of time needed for each system. Though, looking at data from a different viewpoint shows faster progression than at other created wetlands in the USA (4 years compared to +10 years). Possibly the billabong has a better design than other wetlands created today. Unlike many constructed wetlands, the billabong is a research wetland and specific design considerations of hydrology and geomorphology were considered previously. Mitsch and Wilson (1996) point out those individuals who lack proper knowledge of wetland ecosystem processes often carry out wetland creation.

Conclusion

In comparison to reference upland sites the billabong has shown little change in bulk density and percent organic matter. After 4 years of seasonal flooding, it is probably still too soon to classify the soils of the billabong as hydric. But errors, such as inconsistency in sampling from person to person and site differences, contribute to varying results. Therefore, more comprehensive studies are needed to determine whether the mitigation project has succeeded.

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